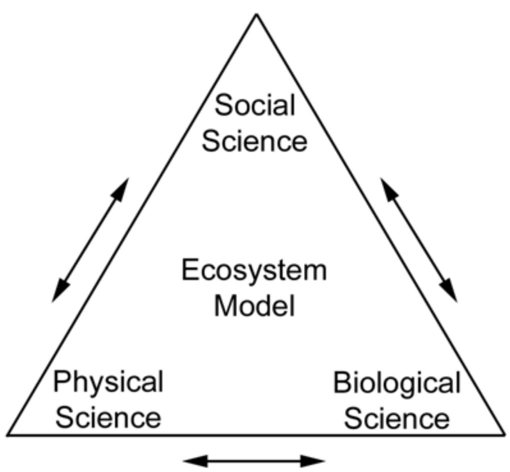
Geology's Role and Importance in Ecosystems

Long ago, John Muir observed that when we try to pick out anything by itself, we find it hitched to everything else in the universe. This certainly holds true when we examine the role and importance of geology in park ecosystems. Geology is a major determinant of the topography, the water and soil chemistry, the fertility of soils, the stability of hillsides, and the flow styles of surface and groundwaters. These factors, in turn, can determine where and when biological processes occur such as the timing of species reproduction and the distribution of habitats. Likewise, biological processes affect geological processes. For instance, biological activity contributes to soil formation and soil fertility, controls hillside erosion, traps blowing sand to form sand dunes, stabilizes drainages, and attenuates floods.

Despite the importance of the physical environment to ecology, the geosciences traditionally have not been integrated into land management or ecosystem planning. This is, in part, because traditional approaches to land management perceived the landscape as a web of biological processes playing out on an inert geological stage as opposed to perceiving the landscape as a collection of processes – biological, geological, and social – that are inter-related and inter-dependent (See Figure 1). Through the last two decades, the focus of land management has slowly been shifting from the former approach to the latter. This changing philosophy brings a need to devote increased attention to the geosciences, and especially to the interactions between the geologic and biological systems.

Figure 1. Relationship of component parts to an ecosystem.



The geologic resources of a park – the soils, the caves, the fossils, the stream network, the springs, the volcanoes, etc. – provide the precise set of physical conditions required to sustain the biological system. Interference with geologic processes and alteration of geologic features inevitably affect habitat conditions. For example, the channelization of the Virgin River in Zion National Park caused the channel to incise, lowering the groundwater table and reducing the habitat of floodplain obligate species (Smith, 1998; Steen, 1999). In Jean Lafitte National Historic Park and Preserve, externally triggered land subsidence is raising the water level in the park inundating the swamp forest and reducing habitat for forest-dependent species (Sauier, 1994). Alternatively, a manipulation of the biological system can trigger changes in the geologic system that can re-affect the biological system. For example, when beavers are trapped to increase the density of hydrophobic shrub species, the river morphology and sediment transport capacity changes resulting in a redistribution of the types of fish species.

A challenge in appreciating the relevance of geology is that geologists often work with very long relative time scales; whereas, life-science specialists deal with much shorter time scales. However, geologic processes occur over a variety of temporal and spatial scales. At one end of the temporal spectrum lie the processes that occur over millions of years such as the rising of a mountain range or the widening of a rift.

At the other end lie the processes that occur virtually instantaneously (and often catastrophically) such as floods, landslides, and earthquakes. Between these extremes are processes that are not easily pinpointed in time but are rapid enough that we can easily observe changes in geologic features as they occur. Often, they occur continuously or in repetitive cycles. Examples of these are shoreline movement, river transport of sediment, soil formation, and cave development.

Geologic processes are as diverse spatially as they are temporally. The absorption of chemical elements to sediment particles may be the key process in determining groundwater chemistries. This process occurs at the microscopic level. In contrast, the geothermal activity at Yellowstone or Lassen Volcanic Park is related to the movement of tectonic plates at a global scale.

Geological processes that most directly impact biological processes include the following: stream and groundwater flow and their variations, erosion and deposition, weathering and mass wasting (landslides, rockfalls), earthquakes, and volcanic phenomena (eruptions, hot springs). These processes collectively operate on a variety of time scales. It is possible for all of these processes to be operating at once in a single park. For example, an eruption in Hawaii Volcano National Park is usually accompanied by earthquakes, though minor, and can include landslides, stream diversion by lava flows, and buildup of topography when the lava flows solidify. These processes destroy some habitats while creating others, and introduce new substrates for early successional stages, thus maintaining habitats for early successional species. (Parrish and Turner)

Even seemingly static geologic resources contribute to ecosystem mosaics and biodiversity. For example, in Grand Canyon National Park, the nesting sites of the spotted owl are restricted to ledges formed in a specific rock layer in the park, the Hermit Shale. Thus, management of the nesting sites of this threatened species requires knowledge of the geologic substrate. Understanding why this rock layer is so important to the owls indicates the need for integrated research. An example of floral dependence on geology is the Winkler's cactus, which grows only on the white, powdery soil and pebbles eroded from part of the Morrison Formation in Canyonlands National Park. In this case, not only is the distribution of the rock layer itself important to the plant, but the erosion products themselves are quite fragile, requiring management of both the plant and its delicate habitat. (Parrish and Turner)